INCLUDING THE FISHERY SYSTEM IN LAND PLANNING

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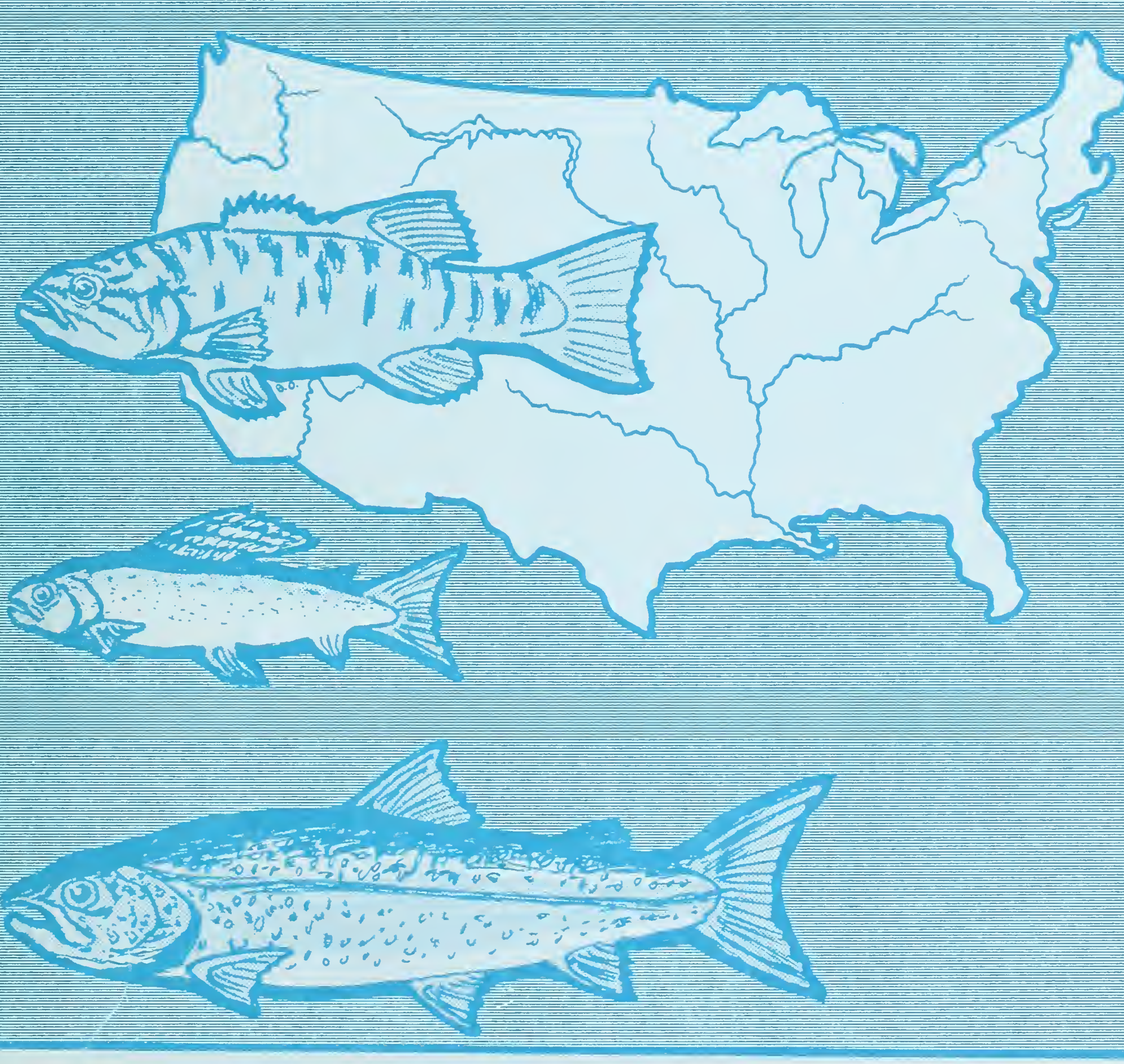

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RESEARCH SUMMARY

The USDA Forest Service uses a geomorphic analysis that classifies units of land in its Land Systems Inventory. This inventory provides managers with a description of the geology, geomorphic processes, and watershed conditions within any given area of land. Similar areas of land can then be identified, classified, and mapped. The inventory information is then used to determine the type and intensity of land uses each of these stratified land areas can provide and still protect the environment and allows land managers to intelligently plan for future land uses. Although the system provides some protection for the aquatic environment, the inventory, built on terrestrial descriptions, does not provide the information needed for managing aquatic resources.

Through the study reported here, a system was developed to integrate all streams and their fisheries into the Land Systems Inventory at the landtype association level and to include most streams and their fisheries at the landtype level of planning. This integration was possible because not only do similar lands have similar vegetation and geology but because similar lands in the natural state also have similar streams and fisheries.

Similar lands have similar fisheries because watersheds influence the development of the abiotic and biotic components of the stream. The abiotic components of the stream dictated fish biomass and species composition. Therefore, fish biomass and species composition can be determined at levels of accuracy needed in land use planning by using the Land Systems Inventory that identifies similar lands. Thus for the first time the landmanager has a planning system covering large areas that includes both the terrestrial and aquatic environments in the final allocation of resources.

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INTRODUCTION

Because they work with aquatic ecosystems on an element-by-element basis, fishery biologists have a difficult time working fishery information into the interdisciplinary processes used in land-use planning (Platts 1976a). This piecemeal approach makes it difficult to present fishery information in a form to meet the requirments of the National Environmental Policy Act of 1969, the Resource Planning Act of 1974, and the National Forest Management Act of 1976.

Fishery information is difficult to integrate into the planning process because inventory methods are too crude to adequately document the fishery (Platts 1976b). Also, biologists do not have a procedure that will unite the fishery information with the terrestrial land system classifications managers rely on for land use planning (Arnold 1975). This report presents a method that can be used to integrate the fishery into a land classification system in selected mountainous lands in Idaho.

To assign streams for resource use managers need information similar to that required to allocate lands as provided in the Forest Services' Land Systems Inventory. Managers must know the inherent capability of streams, the resources the streams produce, and the influences on these stream resources from surrounding land management programs. The Land System Inventory provides biologists with a blueprint that will provide this basic information over broad land areas. This inventory will also allow the information to be used at levels of planning needed to fit the land units used in the planning. Biologists need a nationally accepted planning process that will include the fishery in land use planning. This report demonstrates a method that may work over broad areas of mountainous lands. The report is based on a study that successfully integrated the fishery into a Land Systems Inventory that covered 397 square miles (1,028 km^2) of lands in the South Fork Salmon River, Idaho.

ATTEMPTS TO WORK THE FISHERY INTO LAND PLANNING

The ECOCLASS System

Individuals and teams have attempted for many years to develop ecosystem classification models that would include the aquatic system. Corliss and others (1973)[1] designed ECOCLASS in an attempt to build a single classification system that would unify all systems (terrestrial and aquatic) that would fulfill the needs of both research and management planning. ECOCLASS was designed to be used at all required levels of planning, with the lowest level being the on site or project level. The major failure in ECOCLASS was that the aquatic environment could not be united with the terrestrial environment at levels needed for planning.

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[1]Corliss, J. C., Robert D. Pfister, William S. Platts, and others. 1973. ECOCLASS a method for classifying ecosystems - a task force analysis. USDA For. Serv., Intermt. For. and Range Exp. Stn., Missoula, Mont., 52 p.

Land Systems Inventory

Wertz and Arnold (1972) developed a Land Systems Inventory for the Forest Service that delineates similar mapable land units of the sizes required for planning that could also be used to map similar aquatic units. Their system, capable of covering large areas, demonstrates the benefits of an inventory that has application to land-use planning, decisionmaking, and management because it can fit the different levels of planning from the project level to national level.

Wertz and Arnold's land base units represent many levels (narrow to broad) of environmental descriptions essential for separating the planning unit into successively smaller land components. Within this concept, broad land units can be subdivided into smaller, more homogeneous units; likewise smaller land units in the system can be combined to form broad land units to meet planning objectives.

Wertz and Arnold (1972) provided the first workable model that could unite the condition and capability of the aquatic environment with the condition and capability of the terrestrial environment within the same unit of land.

Soil scientists in the USDA Forest Service, Northern Region, have been classifying and mapping national Forest lands at the landtype level using an almost identical Land Systems Inventory used in the Intermountain Region. Landtypes are visually identifiable units of land resulting from homogeneous geomorphic and climatic processes and range from 1/10 to 1 square mile (2.59 km^2). The Land Systems Inventory was also devised to provide information to meet specific land use planning objectives for the different resource uses (USDA 1976). The Northern Region system of classification incorporates the sciences of geomorphology, geology, soil science, hydrology, and plant ecology, but did not incorporate the fishery. This system did provide information that would assist in determining some environmental conditions that could influence the fishery: (1) average annual precipitation, (2) snow pack conditions, (3) average annual air temperature, (4) stream flow timing, (5) water yield, and (6) sediment pollution hazards.

Wendt, Thompson, and Larson (1975), expanding the work of Wertz and Arnold (1972), developed procedures for use in the Forest Service that would provide mapable land base information useful to all disciplines. This method starts at the physiographic province level and steps down through selected levels to the landtype level. Their goal was the same as Wertz and Arnold's (1972) -- to systematically define the land units within any area in terms of the information required by the planning level.

Because their system focuses on a common land unit, the inventories are easily assembled and readily understood among interdisciplinary scientists. By uniting the stream systems with this land system inventory, information available from other scientists concerning geomorphology, climate, soils, and vegetation can be directly related to the fishery.

Valley Systems Inventory

Cole (1972), in an inventory procedure for stream hydrology, extended the Forest Service Land Systems Inventory down to the valley level of classification. The valley type is a refinement of those landtypes containing valleys that did not originally allow an adequate description of the valley bottoms. By classifying the valley in a form useful for planning, Cole (1972) gave the fishery biologist a planning system that is

only three levels above that needed for intensive fishery planning. Below the valley classification only the habitat type and site levels of information are necessary to fulfill all requirements of planning and management.

Cole's (1972) valley types by themselves would not be adequate for all planning, as the pollution received by a stream often comes from hill slopes as well as the valley bottom. Collotzi (1976) related certain stream physical conditions to valley type but did not include the fishery as it would react to these conditions. Collotzi's (1976) and Cole's (1972) approaches will enhance the Land Systems Inventory when the fishery information can be worked into this level with confidence.

Aquatic-Geomorphic System

Platts (1974) worked the fishery information into the Land Systems Inventory at two of the middle levels of land classification. This study sparked interest among land managers (Pence 1976) and may have initated fishery biologists (Collotzi 1976, Espinosa 1978) to attempt working the fishery into other levels of planning. The approach by Platts (1974) is seldom used because the system demands a reliable data base and the system was worked into the Land System Inventory at only the two levels. Thus the land managers could not use this system at levels they needed for intensive management. This system does have merit in that it moves away from the subjective methods of developing input for land use planning towards a more reliable quantitative approach.

Wetlands Classification

The USDI Bureau of Sport Fisheries and Wildlife (1976) in "Interim Classification of Wetlands and Aquatic Habitats of the United States," presented a method for classifying wetlands and aquatic habitats. This system dealt strictly with aquatic habitats and, at this time, does not allow the fishery to be worked directly into land use planning of surrounding lands or resources. Therefore, without further development this system will not fit into the broad interdisciplinary planning effort.

Bailey's (1976) Regionalization Classification system was used by the Fish & Wildlife Service (1976) for stratifying Wetlands Classification. If the Wetlands Classification is worked into Bailey's (1976) system as Bailey's system is stepped down to describe smaller size land units, (down to at least the landtype level) then the Wetlands system could be worked into land use planning once the fishery was also determined at this level.

Regionalization Classification

Bailey (1976) has recently classified and mapped the United States at the regional level. Terrestrial abiotic and biotic components are classified simultaneously, therefore the system is built on their interrelations and interactions. Because aquatic life is dependent on both the abiotic and biotic parts of the terrestrial environment, as Bailey's (1976) system is stepped down to classify smaller areas of land via the Land Systems methodology, biologists should find it will fit fishery needs.

The ECOSYM System

ECOSYM is being developed and field tested under The U.S. Forest Service SEAM (Surface Environment and Mining) Program by Utah State University (Davis and Henderson 1976). ECOSYM is different from the mapable land unit classification approach developed by Wertz and Arnold (1972), Platts (1974), and Wendt, Thompson and Larson (1975). ECOSYM authors contend that while the classification approach has provided a tool for supplying specific information at particular locations, the information supplied has not been useful or applicable to other locations.

ECOSYM was designed not only to serve as a system for classifying local lands, but also to serve as a general system that will allow information gathered in one area to be used in other areas. The authors of ECOSYM believe that land classification schemes such as Daubenmire's (1968) and ECOCLASS (Corliss and others 1973) are based heavily on subjective criteria and are not applicable to a wide range of management questions.

ECOSYM differs from ECOCLASS in that ECOSYM builds a broadly based information system using separate ecosystem classifications. This framework attempts to include all important ecosystem components to answer specific questions. ECOSYM has yet to be validated, while the Land Systems 5 model has been tested with good results.

The techniques used in this study to work the fishery into a planning system should accomodate either ECOSYM or the Land System Inventory. At present the method is directed toward the Land Systems model, the principal model being used to collect inventory data for land use planning on National Forest lands (Wendt, Thompson, and Larson 1975).

LAND CLASSIFICATION STUDY

Study Objectives

By quantifying components of the stream environment, fish populations and fish community structure within designated land units, the following hypothesis could be tested: similar land units with similar lithology contain similar stream environments and similar fisheries. If this null hypothesis is not rejected, then land classification systems could be utilized to describe and classify streams and fisheries and this information could be worked into the land-use planning process using the land units common to other disciplines.

The objective of this study then was to test the following two phases of the hypothesis: (1) the stream and its fisheries can be worked into the Land Systems Inventory at selected levels of classification; and (2) stream environments and their fisheries can be determined from the land systems classification at the landtype association and landtype levels once the sub-sampling of the stream environment and its fisheries is sufficient.

Study Area

The study area is in the southern portion of the Northern Rocky Mountain physiographic province and is located entirely within the Idaho Batholith (fig. 1). About 397 square miles (1,028 km^2) of the upper 52 miles (84 km) of the South Fork Salmon River (SFSR) drainage in west-central Idaho were included in the analysis. Data were collected from 38 tributary streams by studying 2,482 transects to document streams and streamside environments, and by sampling 291 fish study plots for estimates of fish standing crop and fish community structure.

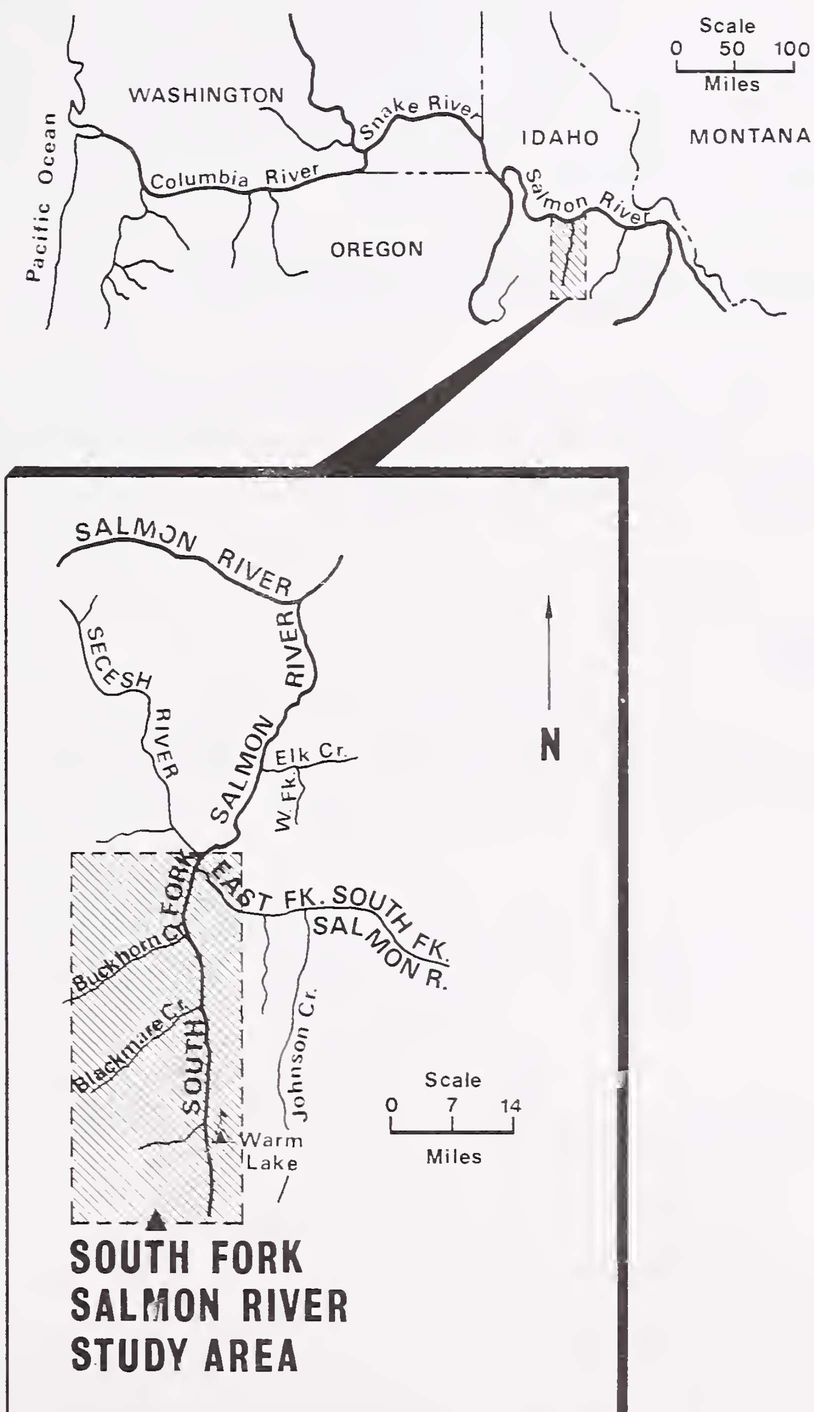

Figure 1.--Location of the study area and its relationship to the Columbia River drainage.

The study area contains a large array of landtypes resulting from land-forming processes occurring since the rise of the batholith. The main land-shaping forces have been streams, glaciers, and mass-wasting processes causing high geologic erosion, especially at the higher elevations. Faulting, folding, and uplift have also played an important but less extensive role in the land-forming processes.

FISHERY

The study area has historically contained the largest salmon run in Idaho composed entirely of summer chinook salmon {*Oncorhynchus tshawytscha* (Walbaum)}. Because of passage problems in lower Snake and Columbia River dams, this run is now only of remnant size. Steelhead trout (*Salmo gairdneri* Richardson), fluvial cutthroat trout (*Salmo clarkii* Richardson), rainbow trout (*Salmo gairdneri* Richardson), Dolly Varden {*Salvelinus malma* (Walbaum)}, brook trout {*Salvelinus fontinalis* (Mitchill)}, mountain whitefish {*Prosopium williamsoni* (Girard)}, sculpin (*Cottus* spp.), dace (*Rhinichthys* spp.), lamprey {*Entosphenus tridentatus* (Gairdner)}, and mountain sucker {*Catistomus platyrhynchus* (Cope)} also occupy the study streams. The study streams often have channel gradients that are too steep for high production of salmonoids, although salmonoids have adapted to almost all streams in the study area.

The study streams seldom receive fishing pressure because of poor access and better fishing in surrounding areas. Thus, fish mortality is due almost entirely to natural causes, and standing crops provide a measure of fish populations under natural conditions. Standing crops of fish yield unbiased estimators of the quality and size of stream environments.

STUDY STREAMS

The average elevation of study streams is 5,653 feet (1,719 m) and stream elevations range from 4,370 to 7,407 feet (1,328 to 2,252 m). The streams occur within 12 different landtypes.

The study streams offer a wide variety of aquatic habitat types representative of mountain streams in the batholith. They study streams are in natural or near-natural condition and water chemistry is uniform (Platts 1974) because the bedrock is almost entirely granitic.

The study area has been landtyped by soil scientists and hydrologists (Arnold and Lundeen 1968) and was one of the first land areas to be typed according to geomorphic processes that formed the lands.

STREAM, FISHERY, AND LAND CLASSIFICATION

Streams

The stream survey was conducted from 1970 through 1972 using methods outlined by Platts (1974) modified from Herrington and Dunham (1967) to increase the accuracy of the environmental descriptions and to add additional descriptors. The methods satisfactorily quantified most aquatic variables because measurements were conducted during clear, low-flow conditions.

The environmental condition of the 38 major tributaries within the study area, totaling 135 stream miles (217 km), was documented by using an average of one transect for every 93 yards (85 m) of stream. Stations were located randomly along study streams from mouth to headwaters until ephemeral stream conditions were encountered. Each station included a cluster of 5 evenly spaced transects with 50-foot (15.3 m) intervals.

A transect (channel cross section) was defined as a line running perpendicular to the centerline of the stream. The following measurements and conditional factors were recorded at each transect:

1. Stream depth at four equal intervals across the transect.
2. Channel substrate particle size classifications.
3. Stream, pool, and riffle widths.
4. Pool rating.
5. Cover, condition, and habitat type of streambanks.
6. Channel elevation and gradient.
7. Fish species and abundance.
8. Landtype association and landtype.

A given transect crossing the stream channel was divided into 1-foot (0.3 m) intervals, and the dominant streambed surface material was classified on each 1-foot section as follows:

Particle diameter	*Classification*
12 inches or over (304.8 mm or over)	Boulder
3 to 11.99 inches (76.1 to 304.7 mm)	Rubble
0.185 to 2.99 inches (4.7 to 76.0 mm)	Gravel
0.184 inch and less (Less than 4.7 mm)	Fine sediment

Stream areas were identified as either pool or riffle. The pools were then classified as to suitability for fish as follows:

Description	*Rating*
Maximum pool diameter exceeds average stream width. Pool is over 3 feet in depth or over 2 feet in depth, with abundant fish cover.	5
Maximum pool diameter exceeds average stream width. Pool is less than 2 feet in depth or if between 2 and 3 feet in depth lacks fish cover.	4
Maximum pool diameter is less than average stream width. Pool is over 2 feet in depth, with intermediate to abundant cover.	3
Maximum pool diameter is less than average stream width. Pool is less than 2 feet in depth, with intermediate to abundant cover.	2
Maximum pool diameter is less than average stream width. Pool is less than 2 feet in depth, with no cover.	1

The condition and type of each streambank were rated using the total streamside area between each transect in accordance with the following tabulation:

Vegetation		*Stability*		*Habitat type (example)*	
Forest	2.0	Excellent	2.0	Sod, root, log	2.0
Brush	1.5	Good	1.5	Brush, rubble	1.5
Grass	1.0	Fair	1.0	Grass, gravel	1.0
Exposed	.5	Poor	.5	Fines, road fill	.5

Station and transect elevations were read with an altimeter to ±40 feet (12 m).

Channel gradients were recorded at each cluster of transects with a clinometer and equalled the average gradient over the entire 200-foot (61-m) study section.

Stream width values refer to surface water widths measured perpendicular to the flow of the stream. Average transect depths were obtained from four equidistant measurements.

Fish Population

A total of 2.75 miles (4.42 km) of stream were sampled at 291 stations, using 4 miles (6.4 km) of prima cord. A 0.13- or 0.23-inch (0.32 or 0.57 cm) mesh net was stretched across the stream to block fish from moving out of the sampling area prior to the explosion. The net and the effectiveness of prima cord assured an unbiased collection of nearly 100 percent of the fish population within each sample area. All collected fish were identified and measured for total length.

Land Classification

The study area was morphogenetically categorized by soil scientists according to dominant geomorphic processes into four landtype associations. These associations were further subdivided into 20 landtypes. The landtype is the lowest level of classification used in this study. Maps with overlays were used to determine the land system unit in which the selected stream or stream area occurred.

The two geomorphic levels of stratification evaluated in this study are part of a system proposed by Wertz and Arnold (1972) that contains the following categorical levels in descending order of hierarchy.

1. Site
2. Landtype phase
3. LANDTYPE
4. LANDTYPE ASSOCIATIONS
5. Subsection
6. Section
7. Physiographic province

RESULTS

This study unified the aquatic system into two levels of the Land Systems Inventory by describing and evaluating the following *basic* aquatic environments components:

Stream channel substrate conditions
Stream channel morphology
Stream channel cover
Water column morphology
Water column movement
Streamside morphology
Streamside cover

The study also correlated the interrelationships of the basic components to the following *manifest* components:

Fish standing crops
Fish community structure
Fish diversity
Fish spatial occurrence

The basic components were then tested to see if similar landtypes within the landtype association had similar components and to determine if different landtype associations had different components. Because there was parallel similarity, this allowed the fishery to be integrated directly into the Land Systems Inventory.

The final results of the integration of the aquatic environment and its fisheries into the Land Systems Inventory appears in appendixes A and B. This unification is the most important part of this study and the detailed description of integration appears in the appendixes only because of its length. The summary analysis that follows explains why the integration was successful and shows how each of the basic and manifest elements relates to the geomorphic classifications used in the Land Systems Inventory.

Stream Environments Within Landtype Associations

The study area was categorized into four landtype associations at the geomorphic process level--glaciated, cryic, fluvial, and depositional. Each association was sufficiently different in aquatic environment to permit separate aquatic stratification. The aquatic types, however, in the depositional land type association could be better stratified by categorizing their association into two subgroups based on whether ice or water had deposited the soils within the association.

ANALYSIS BY BASIC COMPONENT

Stream Channel Gradients

Stream channel gradients in the glaciated lands (table 1) greatly exceeded those of channels in the other landtype associations (fig. 2 and 3). Because mountain slope lands (fluvial landtype association), cryic lands, and valley train lands (depositional landtype association) all have moderately steep channel topography, stream channel gradients in these associations are about the same (fig. 4, 5, 6, 7, 8,).

Figure 2.--Glaciated lands (foreground) which include a cirque basin landtype. The granitic bedrock is hard, unweathered, nonspalling, and slightly to moderately fractured. The depressional nature of the landscape allows for deep percolation and conversion of precipitation to subsurface flow, which regulates streamflow.

Table 1.--*Stream conditions by landtype association (95 percent confidence interval in parentheses)*

Variable	Landtype association: Glaciated		Cryic		Fluvial		Depositional	
Gradient (percent)	10.6	(0.7)	6.6	(2.4)	6.3	(0.2)	6.6	(0.3)
Width (feet)	9	(1.0)	9	(2.4)	15	(.5)	14	(.4)
Depth (inch)	6	(.7)	8	(2.2)	8	(.2)	8	(.1)
Riffle (percent)	44	(4.9)	44	(11.9)	60	(.6)	50	(.4)
Pool (percent)	56	(6.3)	56	(15.1)	40	(.4)	50	(.3)
Pool rating (units)	4.1		3.4		3.9		3.7	
Channel composition (percent)								
Boulder	42	(4.8)	14	(3.8)	35	(2.1)	32	(1.8)
Rubble	16	(1.8)	26	(7.0)	30	(1.5)	25	(1.4)
Gravel	31	(3.5)	20	(5.4)	15	(1.3)	21	(1.4)
Fine sediment	11	(1.2)	40	(10.8)	20	(1.4)	22	(1.5)
Bank environment (units)								
Cover	1.7	(.2)	2.0	(.5)	1.8	(.02)	1.7	(.1)
Condition	1.8	(.2)	1.6	(.4)	1.6	(.04)	1.7	(.1)
Type	1.8	(.2)	2.0	(.5)	1.9	(.02)	1.9	(.02)
Channel elevation (feet)	6569		6151		4971		5626	
Sample size	300		55		858		1218	

Figure 3.--Strongly glaciated landtype, with rocky ridge landtype in the background. Note the U-shape of the hanging valley in the foreground, which disappears into a larger U-shaped glaciated valley.

Figure 4.--Strongly dissected mountain slope landtype, with slopes between 55 to 70 percent and drainage ways spaced less than 500 feet apart.

Figure 5.--Moderately dissected mountain slope landtype, with slope gradients of 45 to 60 percent. Drainages are spaced 500 to 1,500 feet apart. Fluvial lands are usually found between 3,500- to 6,000-foot elevation.

Figure 6.--A cryic landtype association that occurs near glaciated lands. The cryic lands are poor aquifers and provide little surface water for sustained streamflow.

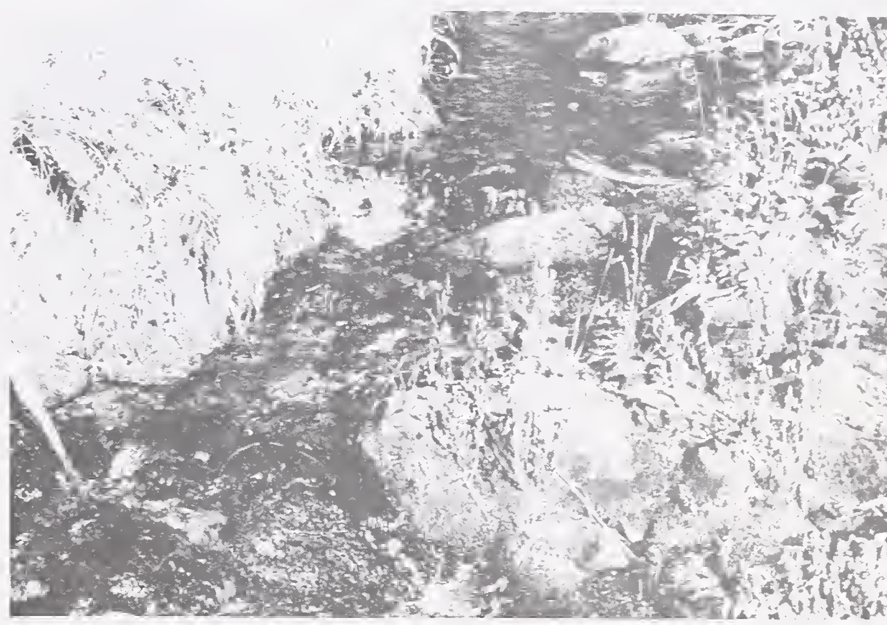

Figure 7.--A typical stream type of the high-elevation valley train landtype, characterized by relatively uniform low flows, very stable banks and channels, and by low and rocky streambanks.

Figure 8.--A valley train landtype along the bottom and lower side slopes of the U-shaped glacial trough. The valley train lands buffer the stream from surrounding steep glacial trough lands and little surface water enters the stream.

Water Column

Glaciated and cryic lands have much smaller streams than do fluvial or depositional lands, with glaciated streams tending to be the smallest (fig. 9). However, stream depths are almost identical among all landtype associations. Streams in glaciated and cryic lands have the highest pool-riffle ratio ratings, which agreed with their lower width-depth ratios. Streams in depositional lands have equal amounts of pool and riffle areas; streams in the fluvial lands are mostly riffles (fig. 10, 11, and 12).

Figure 9.--Dissected fluvial landtype with logging clear-cuts on faulted bench landtype. This entire floor is depositional, mainly composed of the moraine landtype.

Figure 10.--An end moraine landtype bordering Warm Lake, with the surrounding mountainous areas mainly in the fluvial landtype association.

Figure 11.--Example of a stream channel dominated by boulders in an oversteepened canyon landtype downstream from the study area. The channel material in these lands averages larger in particle size than channel material found in most of the other landtypes.

Figure 12.--An aquatic type in the depositional landtype association within the alluvial landtype influenced by upstream disturbed lands. These streambanks have good cover and stability, but the sediment transport rate is high, and gravel and rubble particles tend to be cemented together with fine sediment.

Streamside Environment

Streambanks in the fluvial lands are largely controlled by the valley side slopes, which limited the capability of the stream to build bank pools. Streams in depositional and glaciated lands have more direct influence on their own banks. The high erosion rates, sediment types, and overland water flow in the cryic lands controlled streambank conditions.

Channel Substrate

Stream channels in glaciated lands are mostly boulders and gravel while stream channels in cryic lands are mostly rubble and fine sediment. The differences are probably due to the differential effects of snow, ice, cold air temperatures, degree of rock weathering, and physical action of the glaciers. Stream channels in fluvial lands are dominated by boulders and rubble (fig. 11). Stream substrates in depositional lands are well-balanced in particle size (fig. 12).

Stream Environments Within Landtypes

Twenty landtypes with distinctive soil, water, and landform were subdivided from the four landtype associations. Only eight landtypes had enough stream channel for adequate sampling to determine aquatic-fishery conditions (table 2). Of these eight landtypes (74 percent of the area), streams mainly ran through alluvial, valley-train, and dissected-mountain-slope lands.

Comparative measurments of stream structure, streamside environment, fish numbers, and fish species composition are shown in tables 3 and 4.

It was difficult to classify streams within certain landtypes in the same landtype association, but considerably easier among landtypes of different associations. Nevertheless, structural aquatic differences allowed satisfactory stratification in all associations. Platts (1976b) demonstrated the difficulty of determining factors that control fish standing crops and species composition. As we learn to identify and measure these factors, we will improve our comparisons of stream environments at the landtype level.

Among streams in depositional landtypes, only those on glacially deposited materials differ markedly from those on water-deposited materials. Therefore, the depositional lands were divided into two groups--one composed of materials laid down or worked by water, the other materials laid down or modified by ice. At lower levels of land classification (valley types) these differences in stream environments should automatically stratify.

Table 2.--*Landtypes containing or not containing perennial streams based on the sampling program*

Landtype association	Landtype	Contains streams	
Glaciated			
	Cirque basin	yes	
	Faulted glacial scoured uplands*	occasionally	
	Glacial plastered mountain slope		no
	Glacial scoured mountain slope*		no
	Glacial trough	yes	
	Rocky ridge		no
	Subalpine rim		no
	Toe slope		no
Cryic			
	Uplands	occasionally	
Fluvial			
	Dissected slope	yes	
	Faulted bench		no
	Oversteepened canyon		no
	River spur		no
	Structural basin	occasionally	
Depositional			
	Alluvial	yes	
	Alluvial fan	yes	
	Glacial outwash	yes	
	Moraine	yes	
	Terrace	occasionally	
	Valley train	yes	
	Percent	55	45

*The two landtypes are so similar that often they are considered the same.

Table 3.--*Stream conditions by landtype (95 percent confidence interval in parentheses)*

Variable	Glacial landtype association			Fluvial landtype association	
	Cirque basin	Glacial trough	Glacial scoured uplands	Dissected slope	Structural basin
Gradients (percent)	8.8 (0.9)	13.4 (1.1)	10.1 (2.8)	6.4 (0.3)	5.2 (0.3)
Width (feet)	7 (.5)	10 (1.1)	10 (2.7)	15 (1.8)	11 (1.2)
Depth (inch)	5 (.4)	7 (0.9)	10 (2.1)	8 (.3)	8 (.7)
Riffle (percent)	43 (.4)	40 (.9)	50 (2.2)	60 (.5)	45 (1.6)
Pool (percent)	57 (.5)	60 (1.0)	50 (1.5)	40 (.4)	55 (1.9)
Pool rating (units)	4.3	4.0	3.4	4.0	3.6
Channel materials (percent)					
Boulder	40 (5.4)	50 (7.1)	30 (13.3)	36 (2.1)	31 (10.0)
Rubble	12 (3.0)	22 (5.0)	13 (7.2)	30 (1.9)	17 (6.1)
Gravel	35 (4.9)	24 (5.6)	32 (11.7)	15 (1.3)	9 (3.5)
Fine sediment	13 (3.5)	4 (2.4)	25 (9.9)	19 (1.7)	43 (9.6)
Streambanks (units)					
Cover	1.8 (.05)	1.8 (.04)	1.5 (.1)	1.8 (.02)	1.7 (.1)
Condition	1.9 (.03)	1.9 (.1)	1.5 (.1)	1.6 (.02)	1.2 (.1)
Type	1.8 (.1)	2.0 (.04)	1.4 (.1)	1.9 (.02)	2.0 (.0)
Channel elevation (feet)	6941	5987	--	4977	4788
Sample size	164	104	30	821	30

(con.)

Table 3.--*Stream conditions by landtype (95 percent confidence level in parentheses) (con.)*

Variable	Depositional landtype association									
	Alluvial		Valley train		Alluvial fan		Moraine		Terrace	
Gradient (percent)	3.6	(0.2)	8.3	(0.5)	2.3	(0.3)	4.9	(0.5)	3.0	(0.0)
Width (feet)	17	(1.0)	13	(.5)	13	(1.1)	12	(1.7)	26	(9.3)
Depth (inch)	8	(.5)	8	(.3)	7	(.7)	6	(.7)	16	(2.6)
Riffle (percent)	53	(1.1)	54	(.4)	54	(1.4)	58	(1.1)	65	(7.3)
Pool (percent)	47	(1.0)	46	(.4)	46	(1.0)	42	(1.2)	35	(2.6)
Pool rating (units)	3.7		3.7		3.8		4.1		4.0	
Channel materials (percent)										
Boulder	15	(2.8)	41	(2.4)	16	(5.7)	22	(9.1)	78	(14.3)
Rubble	27	(3.2)	23	(1.7)	23	(5.8)	32	(5.3)	17	(14.0)
Gravel	32	(3.9)	16	(1.5)	21	(5.1)	33	(5.8)	2	(5.8)
Fine Sediment	26	(3.4)	20	(1.9)	40	(7.4)	13	(3.8)	3	(6.6)
Streambanks (units)										
Cover	1.8	(.04)	1.7	(.02)	1.9	(.1)	1.6	(.1)	1.5	(.0)
Condition	1.6	(.06)	1.6	(.03)	1.4	(.1)	1.9	(.4)	1.5	(.0)
Type	1.8	(.05)	1.8	(.03)	2.0	(.05)	1.9	(.04)	1.8	(.4)
Channel elevation (feet)	5614		5675		5422		5530		4310	
Sample size	243		792		67		124		5	

(con.)

Table 3.--*Stream conditions by landtype (95 percent confidence interval in parentheses) (con.)*

Variable	Depositional landtype association Glacial outwash		Cryic landtype assocaition Cyric uplands	
Gradient (percent)	2.7	(0.5)	6.5	(2.4)
Width (feet)	13	(1.3)	9	(1.8)
Depth (feet)	12	(1.3)	8	(1.4)
Riffle (percent)	38	(1.9)	44	(1.3)
Pool (percent)	62	(1.8)	56	(1.6)
Pool rating (units)	2.9		3.3	
Channel materials (percent)				
Boulder	8	(7.1)	12	(6.9)
Rubble	32	(9.1)	26	(8.9)
Gravel	14	(5.9)	20	(8.2)
Fine sediment	46	(10.7)	42	(10.8)
Streambanks (units)				
Cover	2.0	(.0)	2.0	(.03)
Condition	1.4	(.1)	1.6	(.1)
Type	2.0	(.04)	1.9	(.05)
Channel elevation (feet)	5370		6170	
Sample size	30		55	

Table 4.--*Average number of fish by species per station by landtype association*

Species	Landtype association: Glaciated	Cryic	Fluvial	Depositional
Brook trout			0.1	0.3
Chinook salmon			.6	2.0
Cutthroat trout			.1	.1
Dace				.01
Dolly Varden			.3	.5
Rainbow trout	0.2		3.3	1.2
Sculpin			.1	.2
Whitefish				.1
Other			.1	.02
Total fish	0.2		4.6	4.5
Sample number	6	0	108	168

ANALYSIS BY BASIC COMPONENT

Stream channel Gradients

Except for valley train lands, landtypes composed of depositional materials have low channel gradients; alluvial fan lands have the lowest channel gradients. Valley train lands are ice-formed, which probably accounted for steeper stream gradients.

Water Column

Terrace and oversteepened canyon lands are adjacent to the larger streams, so larger streams intercepting these lands were expected. Stream widths and depths between landtype associations were different but similar by landtype. There should be some correlation between stream width and depth as one is influenced by the other. When landtype and landtype phase descriptions and delineations are more refined, it will be easier to determine if similar landtypes have similar stream width and depths. Cryic lands typically contain few streams, and those are small. Pool-riffle ratios were not significantly different among all landtypes in the depositional lands. Streams in glaciated and cryic lands have a higher pool-riffle than streams in dissected mountain slope lands.

Channel Substrate

Stream channel materials showed more differences between landtype association than by landtype; however, channel materials in valley train lands differed from materials in streams in landtypes also composed of depositional materials. The difference is probably due to glacial influence in the valley train lands. Percentage of boulder was higher and fine sediment was lower in streams flowing through glaciated landtypes than in stream channels in cryic lands, where materials had been more stationary.

Stream channels in morainal lands contain the highest percentage of rubble because of the nature of the soil moved by the glacier. Cirque basin lands have the lowest amount of rubble in their stream channels but have the highest amount of gravel. Cirque basin land streams have the highest amount of gravel of all landtypes. Glaciation and nivation are probably the main processes responsible for creating rubble and gravel for these streams.

Channels in landtypes that produce abundant sediment (cryic, dissected slope, and structural basin) and have low channel gradients (glacial outwash and alluvial fan) have more fine sediment in their channels than gravel. The river spur and over-steepened canyon landtypes are high producers of channel sediment to down-drainage streams. In the study area, landtype proximity to streams and the types of sediment sources (roads, fire, etc.) directly affect streams.

Streamside Environment

Streambank stability is influenced by vegetative cover, but this was not properly inventoried or classified within landtypes. Streambank stability and cover usually rated good to excellent throughout the study area; thus differences were small between different landtypes.

Summary

It was not possible to completely classify the stream environment at the landtype level, perhaps because of inadequate sampling, inadequate description of the stream environment, an inadequate landtype classification, or perhaps all three factors. Improving our ability to map and define land units and describe stream environemnts at the landtype level will allow us to classify fishery environments with more accuracy. Most of the stream environments within landtypes can now be described, classified, and worked into the Land System Inventory at landtype and landtype association levels. As research refines this methodolgy and applies it to the valley type and riparian type levels of land stratification, the differences in stream environments at this level should become even more distinct.

Fisheries Within Landtype Associations

Only the cryic landtype association contained streams incapable of producing good fish populations. The strongly glaciated lands were also almost barren of stream fish, with fish occurring only in the glacial trough landtype (tables 4 and 5). In good lake habitat, fish thrive in high-elevation glaciated and cryic lands despite severe winters; however, fish cannot survive in shallow streams during harsh winters.

Streams in depositional and fluvial lands supported almost all of the fish. Streams in the depositional lands were the most productive, although these lands accounted for only 10 percent of the area. Chinook salmon, rainbow trout, cutthroat trout, Dolly Varden, brook trout, and sculpin were found in both the depositional and fluvial landtype associations; rainbow trout were the only species found in the glaciated lands. Sculpin preferred the lower gradient streams in the depositional lands.

Fisheries Within Landtypes

Only eight of the 20 landtypes had streams supporting fish populations of any importance. Although fish were collected in two of the eight landtypes, only one stream in the study area failed to produce fish in the sampling program. All other streams supported fish because most of them flowed through or were influenced by more than one landtype. Streams draining multiple landtypes had higher fish standing crops and more fish species than did streams that drained only a single landtype.

In glaciated lands, only streams in the glacial trough landtype supported fish. Landtypes in the depositional lands contained the most productive streams, with streams in the alluvial lands containing the highest fish standing crops. Because of the higher miles of stream in the valley-train and dissected-mountain-slope landtypes, more fish occur in these two landtypes than the others combined.

Table 5.--*Average number of fish by species per station in landtypes supporting fish*

Species	Alluvial	Terrace	Glacial outwash	Valley train	Alluvial fan
Brock trout	0.8		0.6	0.1	
Chinook salmon	7.1	4.0		.1	5.3
Cutthroat trout				.2	
Dace	.1				
Dolly Varden	.6			.7	.3
Whitefish	.4				
Rainbow trout	.8	6.0	.2	1.4	.5
Sculpin	.4				.3
Other	.1				
Total fish	10.3	10.0	0.8	2.5	6.4
Sample number	35	1	5	102	12

Species	Moraine	Cryic uplands	Cirque	Glacial trough	Dissected mountain slope
Brook trout	0.3				0.1
Chinook salmon	1.3				.6
Cutthroat trout					.1
Dace					
Dolly Varden	.1				.3
Whitefish					
Rainbow trout	2.2			.7	3.3
Sculpin	.5				.1
Other					.1
Total fish	4.4			.7	4.6
Sample number	13	4	8	3	108

Chinook salmon, rainbow trout, cuttroat trout, Dolly Varden, brook trout, and sculpin occurred in streams in landtypes occuring in both the depositional and fluvial landtype associations. Mountain whitefish and dace occupied streams only in the alluvial fan landtypes. Chinook salmon were found mainly in the alluvial and alluvial fan landtypes.

Sculpin preferred lower channel gradients in depositional landtypes, but were not found in the valley train landtype. The predominance of high channel gradients in these streams could have been a factor causing their absence.

The west slope cutthroat trout, widely acknowledged to be a species declining in numbers and range, mainly occupied the valley-train lands. Streams in this landtype were still in the natural state. Nevertheless, the density of the cutthroat trout population was lower than those of rainbow trout or Dolly Varden, and only twice that of chinook salmon and brook trout.

The fact that cutthroat trout were found to occupy only two landtypes could attest to the difficulty this species has in competing with other native as well as exotic species. Brook trout, an exotic species, have much more success in extending their range and numbers across certain landtypes.

The results emphasize the critical problems the west slope cutthroat trout confronts in holding its range and numbers within selected landtypes. The problems may become even more complex as land uses become more diverse and other native or exotic fish species are introduced.

DISCUSSION

The Land System Inventory allows fishery biologists to combine stream descriptions with information of other disciplines. The combined information can then be systematically worked into an inventory of land units appropriate for land use planning. Working aquatic information into the Land System Inventory is important: this system is the major tool for decisionmaking on National Forest lands. Wendt, Thompson, and Larson (1975) found that when considering the seven categories of landform stratification, the landtype association and landtype levels proved to be the most useful to National Forest planning. The landtype level is the basic level of the Land Systems Inventory now being used at the Ranger District level of planning. This study shows the aquatic system can fit into either of the two levels.

The basic framework for combining the aquatic information outlined in this study can also be used to enter the fishery system into lower levels of the Land Systems Inventory as they are developed. Hopefully research will develop the refinement needed in aquatic methodologies that will allow the fisheries to enter into all levels of land use planning. The valley type and aquatic type levels should have the highest research priority.

Fishery biologists should settle on a common approach to land use planning that has credibility, reliability, and preciseness. This study shows that it is possible.

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APPENDIX A

A. Aquatic Environment-Fishery Information at the Landtype Association Level

GLACIATED LANDS

Geomorphic Description

Glaciated lands are found above 6,000 feet (1,830 m) in elevation and occur mainly in the headwaters of the South Fork Salmon River and its tributaries. They include 96,830 acres (39,180 ha) and make up 38 percent of the study area.

These lands, shaped by alpine glaciation, are characterized by straight, U-shaped glacial valleys and a parallel drainage system. Common landforms are cirque basins, headwalls, rocky ridges, and weakly expressed horns.

Aquatic Environment

Streams in the glaciated lands average much smaller and shallower than those in fluvial or depositional lands. They are dominated by pools of poor quality, have high pool-riffle ratios, low width-depth ratios. Channels are dominated by boulders and gravel with low amounts of fine sediments and rubble. These channels contain a higher percentage of gravel and less rubble and fine sediments than channels of other landtype associations.

Stream channels are the highest in elevation of any associations with the heaviest winter icing and the coldest summer water temperatures. Streams in this association lie in U-shaped valleys with wide buffer zones between them and the valley slopes. This results in very little overland water flow carrying sediment into the streams.

Channel gradients are steeper than channels in the other landtype associations because of hanging valleys and the high gradient of the horizontal stairsteps of the glaciated valley. Streambanks are very stable and contain many boulders. Streamside cover is mostly trees and brush.

Low dissolved solids result in clear, infertile water. Streamflow fluctuates less than in any of the other landtype associations.

Fisheries

Fish standing crops and the number of fish species present are extremely low. Glacial trough landtypes supported most of the fish population. Rainbow trout were the dominant species, but the anadromous form of the rainbow trout (steelhead trout) probably does not occur in these lands. Salmon probably never enter these lands. Cutthroat trout and Dolly Varden may inhabit streams of this landtype association, but populations would be extremely low.

CYRIC UPLANDS

Geomorphic Description

Cryic lands form a complex or transition zone below or adjacent to the glaciated lands and include 17,180 acres (6,950 ha), or 7 percent of the study area. Effects of ice and permanent snowfield action are localized. Soil and rock were not carried by major ice currents, as was the case of the glaciated lands. As a result, the lands have subdued topography. Slopes are more gentle and mostly convex in shape.

In most cases, the cryic lands have only weakly expressed drainage development. This is partially due to the dominant slope-forming processes that are thought to be presently active on these slopes. Cryic landscapes are at elevations where nivation, freezing, thawing, wetting, and drying make mass wasting the chief process by which materials are or were moved downslope. These processes keep replacing materials that have been removed by overland flow.

Aquatic Environment

The few streams on cryic lands are small and narrow, but have the lowest width-depth ratio of all streams in the study area. The streams are about equal in size to those in the glaciated lands but much smaller than streams in the fluvial or depositional lands.

Cryic areas have constant subsurface frost churning and soil movement; streams are few and thousands of feet apart. Channel gradients are steep and channel elevations high, but less so than in glaciated lands.

Riffles are scarce. The average quality of pools rated higher than the other landtype associations, which could be due to the lower ratio of width to depth. Because streams mostly face south, water temperatures are higher than those in glaciated lands.

High slope erosion rates result in channels dominated by fine sediments, with the percentage of the fine sediments higher and percentage of boulders lower than in any other landtype association. Percentage of rubble is higher and gravel is lower than in streams in the glaciated lands.

Streambank cover is mostly trees, but stability of the bank rates only good because of the surrounding high rates of soil erosion and soil sliding. Streams are only slightly entrenched and lie in shallow valleys that are between U- and V-shaped. The limited buffer zone near the stream permits direct overland flow of eroded soils into the streams.

Fisheries

If fish are present at all, numbers and number of species are extremely low. It is doubtful if anadromous salmon and steelhead ever use this area.

FLUVIAL LANDS

Geomorphic Description

Fluvial lands, located along the lower mountain slopes, include 114,260 acres (46,240 ha), or 45 percent of the study area. Stream-cut lands provide 80 percent of the naturally occurring sediment reaching the streams.

Seventy-eight percent of the logging and 69 percent of the road construction have been on fluvial lands. These lands usually occur below the 6,000-foot (1,830 m) elevation, are characterized by steep, V-shaped valleys, and have a strongly expressed drainage system.

The dominant geomorphic process is running water, but mass wasting, uplift, faulting, and structural control have also contributed to the shape of these lands.

Aquatic Environment

Streams in the fluvial lands have fairly high channel gradients with a high width-depth ratio, as evidenced by the prevalence of riffles. Percentage of pool is lower and percentage of riffle is higher than in streams of any other landtype association. Although the streams are wide, they tend to be shallow, with poor quality pools.

Stream channels are mainly boulders and rubble, with fine sediments exceeding gravel, which reflects the high rate of soil erosion from the slopes. Streamside cover is mostly trees and brush; bank stability is rated only good.

Streams lie in V-shaped valleys. Very little buffer (floodplain) lies between the stream and valley sides, which permits direct inflow of surface waters and sediment during snowmelt and storms.

Streams in this association have the lowest channel elevation and because of well-weathered bedrock, dissolved solids are higher than in streams of any other landtype association. Therefore, these streams with higher temperatures and nutrients are slightly more fertile than streams in the other associations.

Fisheries

Rainbow trout were the dominant species, followed by chinook salmon, Dolly Varden, cutthroat trout, brook trout, and sculpin. Fish averaged about one per 10 feet (3 m) of stream. Cutthroat trout occurred at only half the population density of which they occurred in the valley train landtype.

DEPOSITIONAL LANDS

Geomorphic Description

The depositional lands of alluvial or morainal origin account for 25,930 acres (10,490 ha) or 10 percent of the study area. These lands were formed by water and glacial deposits and occur mainly as small land units throughout the study area. Except in the Warm Lake Basin, depositional lands make up a small portion of the study area.

These lands are extremely important to the aquatic environment because they include: (1) both sides of streams in the U-shaped glacial trough, (2) terraces adjacent to streams, (3) the morainal, glacial outwash and fluvial deposits, and (4) the glacial deposits that compose the valley train landtype.

1. Water Deposited

Aquatic environment.--Those lands formed by soils deposited by water, within the depositional landtype association, contain the largest streams in the study area and have low channel gradients. Stream width-to-depth ratios are high. These streams build their own banks, but pool quality is still poor, and riffles dominate the stream.

Stream channels have very low percentage of boulders, a high percentage of fine sediments, and abundant gravel and rubble. The high amount of channel gravel, combined with low gradient channel reaches, provides the best salmonid spawning environment in the area.

The wide, flat floodplain between the stream and valley slopes acts as a buffer zone restricting overland water flow and sediment from entering the streams. However, streams usually receive high amounts of sediment from upstream fluvial, glaciated, and cryic lands. Streamside cover is dominated by trees and brush; stability of streambanks is good.

Fisheries.--Streams in these lands contained all of the fish species recorded and the highest number of species of any association. Chinook salmon relied more on these streams for spawning and rearing than on streams in any other landtype association.

Chinook salmon were the dominant species followed by rainbow trout, brook trout, sculpin, Dolly Varden, mountain whitefish, and dace. Cutthroat trout numbers were low. Sculpin numbers were higher in these streams than in streams of any of the other landtype associations.

2. Ice-Shaped or Ice-Deposited Land Association

Aquatic environment.--The depositional lands were separated into the water-deposited and the ice-deposited groups to isolate the streams in valley train landtype which do not resemble the other streams in the depositional association. In doing this, the moraine land streams had to be included with the valley train streams even though they are intermediate between the two groups. Because the valley train streams make up the bulk of the streams in the ice-shaped or ice-deposited group, stream description refers mainly to those in the valley train landtype.

Stream gradients are steep; channels are mainly boulders and are low in gravel and fine sediments. Riffles predominate, with occasional poor quality pools.

The valley train streams usually occur in wide, U-shaped valleys, with wide buffer zones lying between the streams and side slopes. Overland surface water flows and direct sediment entering the stream are low. Streamside cover is dominated by brush and trees.

Fisheries.--Rainbow trout were the dominant species, followed by Dolly Varden, cutthroat trout, brook trout, and chinook salmon. Dace, mountain whitefish, and sculpin were lacking, or populations were extremely low. This was the main landtype association used by the cutthroat trout; however, they averaged only one per 250 feet (76 m) of stream.

Chinook salmon used the lower elevation stream sections for spawning and rearing. Sculpin were lacking, which means these streams may not meet some of the environmental needs of other fish. Sculpin were usually found in the geomorphic types having relatively high densities of fish populations.

APPENDIX B

Aquatic Environment-Fishery Condition at the Landtype Association Level

GLACIATED LANDTYPE ASSOCIATION

Cirque Basin

Geomorphic description.--Cirque basins are amphitheater-like basins, found at the heads of most of the glaciated valleys. Some basins contain small lakes while many of the larger cirque basins have small areas of wet alluvial lands near the lakes. Common inclusions are narrow strips of valley train and toe slope lands.

Aquatic environment.--Stream channel gradients are about equal to channel gradients in valley train landtypes, probably because stream channels are stepped, and often very steep. Cirques produced the smallest, shallowest streams studied.

Streams have more pool than riffle, which is different for batholith streams. The pool-riffle ratio is close to one (50 percent pool, 50 percent riffle) with pool quality being very poor. The stream channel is mostly boulders; very little rubble and fine sediment is present.

Bedrock is hard and does not readily break down to the particle size of bedload materials. For some unknown reason (possible nivation), gravel content was high in the stream channels. Streambank environments are nearly excellent. These streams have the highest-elevation perennial channels in the study area.

Fisheries.--No fish were collected, and if populations do exist, they would be very low because of extreme winter conditions.

Glacial Plastered Mountain Slope

Geomorphic description.--These slopes have been modified by glacial material deposited rather than stripped away by glacial scouring. Slopes are usually benched, with fairly thick mantles of soil. Most of these lands are in glacial troughs and contain considerable rounded rock fragments typical of lateral moraines.

Aquatic environment.--The steepness and location of these lands keep perennial streams from developing or entering.

Fisheries.--This land type did not contain fish.

Glacial Scoured Mountain Slope

Geomorphic description.--These lands consist of steep, benchy mountain shoulders which have been scoured by alpine glaciers. They generally occur downstream from the cirque basin lands and are between subalpine rim lands and glacial trough lands. They are similar to the smooth and weakly dissected glacial trough lands. They do, however, have up to 30 percent rock outcrop, and, as a result of glacial scouring, a thinner mantle.

Aquatic environment.--Because of the steepness and location, these slopes contain few perennial streams over 4 feet (1.2 m) in average width.

Fisheries.--These lands did not contain fish.

Glacial Trough

Geomorphic description.--Glacial trough lands occupy the side slopes of the glacial-formed U-shaped troughs typical of alpine glaciation. The preglaciation slopes have been oversteepened by the ice actions of glaciers. The stream drainage patterns on these lands are usually parallel, compared to the dendritic stream pattern in the fluvial lands.

Aquatic environment.--Because of the steepness of the glacial trough lands, their streams have steeper channels than streams in other landtypes. Stream channels are dominated by boulders, while fine sediments are almost nonexistent because of the hard nonweathered bedrock, high channel elevations, and high channel gradients. Streambank environments are almost excellent in quality.

Fisheries.--Rainbow trout inhabited this geomorphic type but in very low numbers. Winter conditions are extreme, thus this geomorphic type, with its small streams, does not lend itself to producing many fish.

Rocky Ridge

Geomorphic description.--These lands occur mainly in the higher elevation glaciated lands and included the highest ridges, upper slopes, and extremely rocky spur ridges. Talus slopes are common, and the percentage of rock outcrop commonly exceeded 50 percent. Slopes are quite steep, often being 90 percent or more.

Aquatic environment.--The steepness and location of these lands preclude streams from occurring.

Fisheries.--These lands contained no fish.

Subalpine Rim

Geomorphic description.--This area consists of subalpine mountain shoulders, mainly on south- and west-facing slopes. These shoulders were not subjected to severe ice plucking and scouring and since glaciation have not been dissected by streams. The slopes are relatively smooth, straight to weakly convex, and extended from ridgetops to as much as 1,000 feet (305 m) in elevation downslope. The adjacent landforms on north- and east-facing slopes are commonly rocky cirque headlands and cirque basins.

Aquatic environment.--Because of the steepness and location of these lands, streams do not occur.

Fisheries.--Fish do not occur in these lands.

Faulted Glacial Scoured Uplands

Geomorphic description.--These lands consist of severely scoured glacial uplands that average 50 percent rock outcrop, and have been faulted prior to and probably since glaciation. The area is covered by huge faulted granitic rocks, some as high as 30 to 40 feet (9 to 12 m), with isolated pockets of soil between them.

Aquatic environment.--The steepness and location of these lands preclude all but a few isolated streams.

Fisheries.--Fish did not occur in these lands.

Steep Rocky Cirque Headlands

Geomorphic description.--These lands are the steep, rocky, ice-plucked cirque headlands of minor drainages, located above the cirque basin. Their granitic bedrock is hard, unweathered, nonspalling, and moderately fractured. The aspect is predominantly north; the elevation between 7,000 to 9,000 feet (2,130 to 2,740 m); and the slope gradient between 60 to 75 percent.

Aquatic environment.--Because of the steepness and location of these lands, they do not contain streams.

Fisheries.--Fish did not occur in these lands.

CRYIC LANDS

Cryic Landtype

Geomorphic description.--Cryic uplands were not subjected to the scouring action of the nearby glaciated lands and are the result of the climatic changes brought about by glaciers. These lands are thought to have been formed by the processes and effects of permanent snow and ice field action; any movement of materials was local. Generally, they have not been dissected to any great degree by fluvial processes.

Aquatic environment.--Stream channel gradients are lower than in any of the glaciated lands. Streams had a difficult time forming in these lands because of the high percolation rates and their landscape position. The few streams that do form are very small.

Most of the stream is made up of pool, with a pool-riffle ratio about 1:1. Boulders are lacking in the channels, probably due to the weathered bedrock. These lands are high producers of fine sediment, which is plentiful in stream channels.

The streambank cover is dominated by trees, but the high amount of incoming fine sediments lowers the bank stability. Stream channels are at high elevations because they occur in ice-modified lands.

Fisheries.--Fish could not be found in these streams. If fish do exist, numbers would be extremely low.

FLUVIAL LANDS

Faulted Bench Lands

Geomorphic description.--This special group of lands results from remnants of block (normal) faulting activity. The block faulting resulted in low, benchlike ridge systems which, in many cases, have been modified by glacial outwash deposits and are moderately to weakly dissected by streams.

Faulted bench, structual basin, and river spur are not true fluvial types but are included under fluvial because, since their formation, they have been altered or formed by fluvial processes.

Aquatic environment.--These lands composed a small portion of the study area and contain a few small streams.

Fisheries.--Streams in these lands contained no fish.

Dissected Mountain Slope Lands

Geomorphic description.--Dissected mountain slope lands consist of slopes incised by streams. Stream cutting was the dominant slope-forming influence. Streams usually form a dendritic drainage pattern.

Aquatic environment.--The streams flow in V-shaped valleys, with little buffer in between the stream and the slopes to stop surface water and sediment from directly entering the stream. Channel gradients are high but not as high as stream channels in the glaciated lands. Usually, streams receive water from streams at higher elevations and tend to be larger than streams in other geomorphic types.

Streams are mostly riffles; pool quantity and quality is low. Because of the steep side slopes of the valley and channel downcutting, boulders and rubbble dominate the stream channels. Percentage of fine sediments is higher than gravel because of the high rate erosion. The streambanks have good vegetative cover and stability.

Fisheries.--These streams averaged about 1 fish per 10 feet (3 m) of stream. Populations were mainly rainbow trout followed by chinook salmon, Dolly Varden, cutthroat trout, brook trout, and sculpin. Besides valley train lands, this was the only landtype cutthroat trout were found in.

Adult chinook salmon use the lowest elevation sections of the streams for spawning and the young for rearing. Rainbow trout averaged 1 fish per 15 feet (4.5 m) of stream.

Oversteepened Canyon Lands

Geomorphic description.--These lands range from steep to extremely steep. They include the moderately to strongly dissected mountain slopes adjacent to the SFSR. They contain second or third order streams that flow directly into the main river; therefore, there was a difference of two or four stream orders between streams in this geomorphic type and the SFSR.

Aquatic environment.--No sampling was done in these lands because they made up only a small portion of the study area. Streams formed completely within this geomorphic type are usually short, have extremely steep channel gradients, and have little productive habitat to offer the fishery. This description is not valid for the SFSR which flows through segments of oversteepened canyon lands.

Fisheries.--Streams other than the SFSR did not provide the habitat required by fish.

Structural Basin Lands

Geomorphic description.--These lands have been modified on site or displaced from their original position by faulting, and therefore occupy a lower position in elevation than they previously occupied.

Aquatic environment.--Because streams were scarce, sampling was minimal. The streams are usually located in the headwaters and therefore were very small.

Fisheries.--These small streams are only capable of supporting low numbers of small fish.

River Spur Lands

Geomorphic description.--The river-spur lands are knoll-like ridge remnants, seldom more than 40 acres (16 ha), and adjacent to the SFSR. They now occur in positions formerly occupied by the river. They were separated from the main mountain slopes by the force of the river cutting through fractures and least-resistant rocks.

Aquatic environment.--These isolated tracts do not contain streams and only border streams originating in other geomorphic types.

Fisheries.--These lands contained no fish.

DEPOSITIONAL LANDS

Alluvial Fan

Geomorphic description.--The alluvial fans are cone-shaped alluvium that was deposited by streams flowing onto a level plain or meeting a stream with less energy.

Aquatic environment.--Streams have exceptionally low channel gradient because the fan developed in areas of gentle slope. Stream size is comparable to other landtypes. Riffle makes up slightly more than half the stream making the pool-riffle ratio about 1:1.

The alluvial fan contains high amounts of boulders. Therefore, stream channels are dominated by boulders. Streambank vegetation is abundant but the material of the fan causes reduced streambank stability. Channel elevations average about the same as channel elevations averaged for all streams sampled.

Fisheries.--Chinook salmon use these low gradient streams for rearing and spawning. Salmon were the dominant species, followed by rainbow trout, Dolly Varden, and sculpin. Chinook salmon averaged 1 fish per 10 feet (3 m) of stream, while rainbow trout only averaged 1 fish per 100 feet (30 m) of stream. The occurrence of sculpin indicated a favorable environment for other fish.

Alluvial Lands

Geomorphic description.--The alluvial lands border streams and include river wash, bottom lands, and first-terrace land positions. They also occur in high mountain meadows where there may be alluvial deposits caused by high water tables.

Aquatic environment.--Streams in this geomorphic type are large, with low channel gradients compared to other study streams. The streams contain slightly more riffle than pool, with a pool-riffle ratio close to 1:1. The stream channel is slightly low in boulders and slightly high in fine sediments, with equal amounts of rubble and gravel.

Streambanks have good cover and stability. Channel elevations are fairly high at 5,614 feet (1,711 m) average, because these lands occur mainly in the headwaters of the SFSR drainage.

Fisheries.--Fish numbers are high, with an average of 1 fish per 5 feet (1.5 m) of stream. Chinook salmon were the dominant species, followed by brook trout, rainbow trout, Dolly Varden, mountain whitefish, sculpin, and dace. More fish species occurred in this geomorphic type than in any other type.

Cutthroat trout were not found in the sampling program and if they do occur populations are extremely low. The low channel gradients and abundant sources of channel gravel resulted in the best spawning environments found for salmonids in any of the geomorphic types. These lands contain the most productive fish habitat of the 20 landtypes.

Moraine Lands

Geomorphic description.--The ground moraines have been reworked by running water and have had glaciated outwash materials deposited on them. These lands range from nearly level to gently sloping, with low hummocky relief. Depressions are generally noncobbly for the first few feet in soil depth; soils are generally nonstratified.

Aquatic environment.--Stream channel gradient is low because the glaciers deposited morainal materials in areas with gentle topography. Stream size and channel elevations are about the same as the average for all study streams combined. There is slightly more riffle than pool, with a pool-riffle ratio close to one.

Pool quality is poor. Possibly because of the morainal type materials, channel substrates are high in percentage of gravel and rubble and low in fine sediments. Streambank stability is good, but streamside vegetative cover is less abundant than the average for all study streams.

Fisheries.--Rainbow trout were the dominant species collected, followed by chinook salmon, sculpin, brook trout, and Dolly Varden. Sculpin numbers were higher per length of stream than found in any other geomorphic type. Chinook salmon use the area for spawning and rearing. Streams average about 1 fish per 10 feet (3 m) of stream.

Glacial Outwash Lands

Geomorphic description.--This landtype is similar to the moraine landtype and includes the smooth, flat landscape in the Warm Lake basin and the terrace lands adjacent to the SFSR. Materials in the outwash lands are stratified while the materials in the moraines are well mixed. Also, glacial outwash lands have a smooth micro-relief compared to the hummocky micro-relief of the moraine land.

Aquatic environment.--These lands are restricted to the Warm Lake basin and contain only a few short sections of stream.

Fisheries.--Fish numbers were low, averaging less than 1 fish per 50 feet (15 m) of stream. Brook trout was the dominant species followed by rainbow trout. Sculpin, most plentiful in streams having the most fish per length of stream, were not collected in these lands.

Valley Train Lands

Geomorphic description.--Valley train lands comprise the bottoms and lower side slopes of the U-shaped glacial troughs.

Aquatic environment.--Although this landtype made up only 4.5 percent of the study area, streams in this geomorphic type are the most important of the streams in the higher elevations. Channel gradients are high because the ice-deposited materials have higher valley gradients than water-deposited materials. Because of the wide U-shaped glaciated valley, the streams have excellent buffer zones to eliminate overland surface flows and sediment from the valley slopes from entering the stream.

Streams have slightly more riffle than pool, with a pool-riffle ratio close to 1:1. Pool quality is better than for the average study stream. Stream channel materials are dominated by boulders and low in gravel.

Fine sediments in the channel are high for streams having such high channel gradients. Streambank cover and stability is good; channel elevations are high because all streams are in glaciated valleys.

Fisheries.--Fish averaged 2.5 per 50 feet (15 m) of stream. Rainbow trout was the dominant species followed by Dolly Varden, cutthroat trout, brook trout, and chinook salmon. This geomorphic type was the mainstay of the cutthroat trout and contained most of the Dolly Varden population. Sculpin were absent, possibly because of the high channel gradients causing high stream power.

Terrace Lands

Geomorphic description.--These flat to gently sloping lands were previously deposited by the larger streams. The deposits were once entrenched and dissected; they are now only remnants of once larger landforms. These river terraces were probably deposited as glacial outwash during one of the Pleistocene glacial intervals and then left in their present elevated position by the entrenchment of streams.

Aquatic environment.--Because these lands now hang on the valley sides, they do not form or offer much passage to streams except along the main river. Some of these lands are still low enough to be adjacent to the stream.

Fisheries.--The few streams that do contact these lands are large. Only one station was in terrace lands, and it recorded 1 fish per 5 feet (1.5 m) of stream. Rainbow trout and chinook salmon were the only fish recorded.

Toe Slope Lands

Geomorphic description.--Lands form the toes of glacial troughs and dissected mountain slopes. Soil are primarily colluvial deposits at the base of the higher adjacent slopes. Slopes are well vegetated (predominantly timber) and are straight to concave. Slopes have 30 to 55 percent gradient and are 50 to 1,000 feet (15 to 305 m) long, at elevations of 4,000 to 5,500 feet (1,220 to 1,680 m). Toe slope land occurs in units that are large enough to delineate consistently at the toes of glacial troughs and mountain slopes.

Aquatic environment.--The location and composition of the soils usually precludes perennial streams, which eliminated them from the random sampling system.

Fisheries.--These lands did not support fish.

Platts, William S.
1979. Including the Fishery System in Land Planning. USDA For. Serv. Gen. Tech. Rep. INT-60,37 p. Intermountain Forest and Range Experiment Station, Ogden, Utah 84401.

Presents a system for integrating streams and fisheries into the Land Systems Inventory--the geomorphic analysis used by the USDA Forest Service to determine type and intensity of land use that can be permitted without environmental damage. As originally designed, the Land Systems Inventory did not adequately consider the aquatic environment and fisheries. The Land Systems Inventory as now amended is now suited to classifying and audocating uses over large areas of mountainous terrain, including terrestrial and aquatic environments.

KEYWORDS: fishery, geomorphic, land use, planning, land classification, stream classification.

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